

## LED Polarimeter

### DESCRIPTION

#### FIELD OF THE INVENTION

[Para 1] This invention is related to polarimeters and more particularly to Senarmont-compensator-type polarimeters.

#### BACKGROUND OF THE INVENTION

[Para 2] Polarimeters are used to view and quantitatively measure stress in glass and other photoelastic materials. When isotropic, photoelastic materials, such as glass and some plastics, are stressed, they become anisotropic. The anisotropy within the material makes the stressed areas birefringent. With a polarimeter, one can determine the degree of anisotropy by observing the degree birefringence. This can then be related qualitatively and quantitatively to the amount stress within the material.

[Para 3] Polarimeters generally consist of a light source, a first polarizer, a  $\frac{1}{4}$  wave plate and a second rotatable polarizer. In order to observe the birefringence, a sample of the material is placed between the first polarizer and the  $\frac{1}{4}$  wave plate. Any stress with a principal axis  $45^\circ$  to either polarizer will appear as a bright area in a dark background. The intensity of the bright area is proportional to the amount of stress. By rotating the second polarizer, the birefringence can be cancelled causing the bright area to become extinct (dark). The degrees of rotation can be converted to a measurement of the phase shift in the light (birefringence) by multiplying the dominant wavelength

of light and dividing by  $180^\circ$ . This results in a measurement of the birefringence that can be converted into the stress intensity by dividing by the stress optical coefficient and the optical path length.

[Para 4] A common light source for a polarimeter is an incandescent lamp. Although this produces a smooth spectrum of white light, nearly 85% of the energy input to the lamp is converted to heat. This excessive heat causes damages to the polarizing film of the first polarizer which is adjacent to the lamp. Over a relatively short period, the damage to the film diminishes the ability to measure stress.

[Para 5] A second disadvantage with incandescent lamps and other white light sources is chromatic aberrations. As the birefringence in the material increases, the longer, red wavelengths will resolve at different positions (degrees of rotation) of the second polarizer from the shorter, blue wavelengths. This creates two overlapping images which makes it increasingly difficult to properly resolve birefringence of  $> 60$  nm. The error in the measurement increases with the degree of birefringence. As a result, what should be a relatively simple and repeatable measurement becomes one requiring a great deal of skill and experience and exhibiting a high degree of variation from one operator to another.

[Para 6] Some polarimeters use compact fluorescent lamps to diminish the damage to the polarizing film from heat. However, this greatly increases chance for chromatic aberrations. When a polarimeter lamp fails, it must be replaced with a reasonably exact duplicate otherwise the difference in the emission spectrum will shift the calibration of the polarimeter. In the case of fluorescent lamps, it is easy to make a mistake since the emission spectrum of a fluorescent lamp is a function of the phosphors used in its manufacture, e.g., there are several "colors" of white for commercial fluorescent lamps. Likely,

the operator will be unaware of the color shift of the lamp and therefore not able to compensate for it.

[Para 7] Thus, it would be an advantage to have a light source for a polarimeter which would overcome these difficulties.

## SUMMARY OF THE INVENTION

[Para 8] It has been discovered that the disadvantages of the prior art may be essentially eliminated by using an LED light source. In particular, the LED source is relatively monochromatic which essentially eliminates errors which were caused by chromatic aberrations. Furthermore, the LED light source is an efficient, low power device that generates only a minimal amount of heat so that there is no damage to the polarizing film. A typical LED device used in this invention consumes only 6 watts of power compared to 60–100 watts for an incandescent source and roughly 25 watts for a compact fluorescent source. Moreover, LEDs have such long lifetimes, >60,000 hours, that replacement may not be required.

[Para 9] The LED polarimeter of this invention comprises a sequential arrangement of an LED light source, a first polarizer, a  $\frac{1}{4}$  wave plate, and a second polarizer substantially aligned along a central axis. The orientation of the first polarizer to the  $\frac{1}{4}$  wave plate is fixed and the second polarizer is rotatable about the central axis. In a preferred embodiment, the LED light source emits in the green wavelength region from about 510 nm to about 540 nm. The human eye is particularly sensitive to green light which makes the analysis easier, and commercially available optics tend to be optimized for the green portion of the visible spectrum.

[Para 10] An additional benefit of the LED light source is that its compact, lightweight design together with its low power consumption allows for the construction of a smaller, portable instrument. For example, one commercially available polarimeter has an 8-inch diameter base, is 11 inches tall and weighs 11 pounds whereas one embodiment of the polarimeter of this invention has a 6x6 inch base, is 8 inches tall and weighs only 5 pounds.

### BRIEF DESCRIPTION OF THE DRAWINGS

[Para 11] Fig. 1 is a schematic view of the LED polarimeter of this invention.

### DETAILED DESCRIPTION OF THE INVENTION

[Para 12] For a better understanding of the present invention, together with other and further objects, advantages and capabilities thereof, reference is made to the following disclosure and appended claims taken in conjunction with the above-described drawing.

[Para 13] Referring to Fig. 1, there is shown a schematic view of the LED polarimeter of this invention. The LED light source 15 is located adjacent to and below first polarizer 3. A  $\frac{1}{4}$  wave plate 7 is suspended over the first polarizer 3 and below second polarizer 5. The supporting structure (shown in dotted-line contour) comprises base 11, vertical support 18 and adjustable holder 2. Generally, the LED source 15 and first polarizer 3 are supported and attached to base 11 which is connectable to or contains a source of electric power. The  $\frac{1}{4}$  wave plate 7 and second polarizer 5 are located in the adjustable holder 2 which is attached to vertical support 18 in a manner which allows for vertical movement of the holder 2 along the central axis 20.

**[Para 14]** The LED light source 15, the  $\frac{1}{4}$  wave plate 7 and the first and second polarizers 3, 5 are substantially aligned along central axis 20. Material sample 10 is placed between the first polarizer 3 and  $\frac{1}{4}$  wave plate 7 in order to measure its birefringent properties.

**[Para 15]** The first and second polarizers 3, 5 are made of a polarizing film, preferably with an extinction ratio of about 10,000:1 or greater. The first polarizer 3 is held in position by base 11 and the  $\frac{1}{4}$  wave plate is held in position by holder 2 such that the orientation of the first polarizer 3 is fixed with respect to the  $\frac{1}{4}$  wave plate 7. The second polarizer 5 is rotatable about central axis 20 and has indicia suitable for determining the degree of rotation.

**[Para 16]** The LED light source 15 preferably yields a generally uniform illumination field. An example of a suitable LED light source is OSRAM Opto Semiconductors' MARKERlight No. OS-ML02A-T. This flat device uses 40 green-emitting LEDs (528 nm) to edge light a printed screen. This arrangement produces an even 2x2 inch field of illumination at about 1200 cd/m<sup>2</sup>. When used in combination with the other components of the polarimeter, this makes for a very dark background and a very bright subject which greatly facilitates the measurement.

**[Para 17]** While there have been shown and described what are present considered to be the preferred embodiments of the invention, it will be apparent to those skilled in the art that various changes and modifications can be made herein without departing from the scope of the invention as defined by the appended claims.